WARM-UP METHOD AND WARM-UP SYSTEM FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The invention relates to a warm-up method and a warm-up system for an internal combustion engine equipped with a CO_2 absorbing and releasing agent.

2. Description of Related Art

[0002] A CO_2 absorbing and releasing agent that absorbs CO_2 in a temperature range approximately at 500 °C, and releases the absorbed CO_2 in a temperature range higher than the aforementioned temperature range has been well known as disclosed in publication titled TOSHIBA REVIEW (vol. 56, no. 8 (2001) pp. 11-14). The similar technology is also disclosed in JP-A-11-262631.

[0003] The CO_2 absorbing and releasing agent that has been heated to reach a substantially high temperature range equal to or higher than 500°C releases CO_2 at high temperature. It has not been considered to use such high temperature CO_2 for warm-up of the internal combustion engine.

SUMMARY OF THE INVENTION

[0004] It is an object of the invention to provide a warm-up method and a warm-up system for an internal combustion engine for promoting the warm-up of the internal combustion engine using CO_2 released from the CO_2 absorbing and releasing agent.

[0005] A warm-up method for an internal combustion engine is provided with a CO_2 absorbing and releasing agent so as to be able to absorb CO_2 contained in an exhaust gas in a first temperature range, and to release the CO_2 absorbed therein in a second temperature range that is higher than the first temperature range. In the warm-up method, a temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range so as to supply the CO_2 released from the CO_2 absorbing and releasing agent into a component of the internal combustion engine.

[0006] In the above-described warm-up method for the internal combustion engine, the high temperature CO_2 released from the CO_2 absorbing and releasing

agent may be supplied to the components of the internal combustion engine so as to be quickly warmed up.

[0007] In the warm-up method, an exhaust gas purification catalyst that purifies the exhaust gas discharged from the internal combustion engine, or at least one of an intake manifold and a cylinder of the internal combustion engine may be set as the component that needs to be warmed. As the exhaust gas purification catalyst performs its catalytic function at a temperature equal to or higher than the catalytic activation temperature, it has to be heated to reach the catalytic activation temperature and higher as quickly as possible. As the intake manifold or the cylinders have been in cold states upon cold start-up, they have to be warmed up as quickly as possible. The high temperature CO_2 may be supplied to the aforementioned components so as to be quickly warmed up. This makes it possible to restrain deterioration in the exhaust emission or to improve startability of the internal combustion engine.

[0008] In the warm-up method, the temperature of the CO_2 absorbing and releasing agent may be increased to be brought into the first temperature range after a command for stopping the internal combustion engine is issued, and the temperature of the CO_2 absorbing and releasing agent may further be increased to be brought into the second temperature range after a command for starting the internal combustion engine is issued. As the CO_2 may be absorbed by the CO_2 absorbing and releasing agent at the aforementioned timing, it may be reliably supplied to the components that have to be warmed-up upon next start-up. The CO_2 is released from the CO_2 absorbing and releasing agent after a command for starting the engine is issued. This makes it possible to improve startability of the engine by warming up the intake manifold, the combustion chamber and the like. The timing for increasing the temperature of the CO_2 absorbing and releasing agent to reach the second temperature range is not limited to the one as described above. If the temperature of the exhaust gas discharged from the internal combustion engine is low, for example, in the idling state continued for a long time, the temperature of the exhaust gas purification catalyst may be decreased to be below the catalytic activation temperature. It is possible to increase the temperature of the CO_2 absorbing and releasing agent to reach the second temperature range at the aforementioned timing so as to warm up the exhaust catalyst.

[0009] A warm-up system for an internal combustion engine is provided with a CO_2 absorbing and releasing agent so as to be able to absorb CO_2 contained in an exhaust gas in a first temperature range, and to release the CO_2 absorbed therein in a

second temperature range that is higher than the first temperature range, the CO_2 absorbing and releasing agent being provided to supply the CO_2 released therefrom to a component of the internal combustion engine. The warm-up system is provided with a heating unit that increases a temperature of the CO_2 absorbing and releasing agent, and a temperature control unit that controls an operation of the heating unit such that the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range.

[0010] In the above-described warm-up system for the internal combustion engine, the CO_2 absorbing and releasing agent is provided so as to be able to supply CO_2 to components of the internal combustion engine, and the heating unit increases the temperature of the CO_2 absorbing and releasing agent to reach the second temperature range. Supply of the CO_2 to the components of the internal combustion engine may allow the internal combustion engine to be warmed up as quickly as possible.

[0011] The warm-up system may employ an electric heater as the heating unit. The warm-up system according to the invention may be formed into a compact body by providing the electric heater within the CO_2 absorbing and releasing agent.

[0012] The warm-up system is provided with an EGR passage that connects an exhaust passage and an intake passage of the internal combustion engine, and an EGR valve that selects an operation between connection and disconnection of the EGR passage. In the warm-up system, the CO_2 absorbing and releasing agent is provided in the exhaust passage upstream of a joint portion between the EGR passage and the exhaust passage, an exhaust gas purification catalyst as the component that needs to be warmed is provided downstream of the joint portion, and the temperature control unit controls an operation of the EGR valve such that the EGR passage is disconnected when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. The EGR passage is blocked as aforementioned so as to prevent the CO_2 released from the CO_2 absorbing and releasing agent from flowing into the intake passage. This makes it possible to increase the quantity of CO_2 supplied to the exhaust gas purification catalyst, promoting the warm-up of the exhaust gas purification catalyst.

[0013] The warm-up system is provided with a turbo charger having a variable nozzle in an exhaust turbine. In the warm-up system, the CO_2 absorbing and releasing agent is provided in the exhaust passage upstream of the turbo charger, an

exhaust gas purification catalyst as the component that needs to be warmed is provided downstream of the turbo charger, and the temperature control unit may open the variable nozzle when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. Opening of the nozzle may reduce the pressure loss between the CO_2 absorbing and releasing agent and the exhaust gas purification catalyst. Accordingly amount of CO_2 to be supplied to the exhaust gas purification catalyst is increased to promote the warm-up of the exhaust gas purification catalyst.

[0014] The warm-up system is provided with a turbo charger having a variable nozzle in an exhaust turbine. In the warm-up system, the CO_2 absorbing and releasing agent is provided in the exhaust passage downstream of the turbo charger, an exhaust gas purification catalyst as the component that needs to be warmed is provided downstream of the turbo charger, and the temperature control unit may close the variable nozzle when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. In the case where the CO_2 absorbing and releasing agent is provided downstream of the turbo charger, the nozzle is closed to prevent the released CO_2 from flowing to the upstream of the turbo charger. This makes it possible to increase the amount of the released CO_2 to be supplied to the exhaust gas purification catalyst downstream of the turbo charger, thus promoting the warm-up of the exhaust gas purification catalyst.

[0015] The warm-up system is provided with an EGR passage that connects an exhaust passage and an intake passage of the internal combustion engine and an EGR valve that selects an operation between connection and disconnection of the EGR passage. In the warm-up system, the CO_2 absorbing and releasing agent is provided in the exhaust passage upstream of a joint portion between the EGR passage and the exhaust passage, at least one of an intake manifold and a cylinder of the internal combustion engine is employed is employed as the component that needs to be warmed, and the temperature control unit may control an operation of the EGR valve such that the EGR passage is connected when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. The EGR passage is connected to admit the released CO_2 into the intake passage via the EGR passage. Accordingly the CO_2 may be supplied from the EGR passage into the intake manifold or the cylinders so as to promote the warm-up.

[0016] The warm-up system is provided with a turbo charger having a variable nozzle in an exhaust turbine. In the warm-up system, the temperature control unit may close the variable nozzle when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. The flow of the CO_2 into the exhaust passage downstream of the turbo charger may be prevented by closing the nozzle as aforementioned. Accordingly more amount of CO_2 is admitted into the intake passage via the EGR passage, promoting the warm-up of the intake manifold or the cylinders.

[0017] In the warm-up system, the internal combustion engine is provided with a throttle valve. According to the invention, the temperature control unit may close the throttle valve when the temperature of the CO_2 absorbing and releasing agent is increased to be brought into the second temperature range. The outer air at the temperature lower than that of the released CO_2 may flow through the throttle valve that has been opened, thus interrupting the warm-up function of CO_2. The throttle valve is closed to prevent introduction of the outer air.

[0018] In the warm-up system, the temperature control unit may control the heating unit to increase the temperature of the CO_2 absorbing and releasing agent to be brought into the first temperature range after a command for stopping the internal combustion engine is issued, and to further increase the temperature of the CO_2 absorbing and releasing agent to be brought into the second temperature range after a command for starting the internal combustion engine is issued. The startability of the internal combustion engine may be improved through supply of CO_2 to the intake manifold or the cylinders upon start-up of the internal combustion engine by adjusting the temperature of the CO_2 absorbing and releasing agent. The deterioration in the exhaust emission may be restrained by quickly warming the exhaust gas purification catalyst to reach the catalytic activation temperature and higher.

[0019] As described above, the invention may improve startability in the internal combustion engine by supplying the high temperature CO_2 released from the CO_2 absorbing and releasing agent into the intake manifold or the cylinders. As the CO_2 is supplied to the exhaust gas purification catalyst to quickly warm the catalyst to reach the catalytic activation temperature and higher, the deterioration in the exhaust emission may be restrained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of preferred embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

Fig. 1 is a schematic view of an example of an internal combustion engine in which the warm-up system of the invention is employed;

Fig. 2 is an enlarged view of a CO_2 absorbing and releasing agent shown in Fig. 1;

Fig. 3 is a flow chart of a control routine for heating an intake manifold to be warmed up;

Fig. 4 is a flow chart of a control routine of a heater for heating an exhaust gas purification catalyst to warm up the exhaust gas purification catalyst;

Fig. 5 is a flow chart of a control routine of a heater for heating a CO_2 absorbing and releasing agent that is allowed to absorb CO_2;

Fig. 6 is a routine of calculating a total amount of CO_2 absorbed in the CO_2 absorbing and releasing agent;

Fig. 7 is another embodiment of the internal combustion engine in which the warm-up system of the invention is employed; and

Fig. 8 is a flow chart showing a control routine of a heater for heating an exhaust gas purification catalyst to be warmed up, which is executed by the ECU shown in FIG. 7.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0021] Fig. 1 shows an example of the internal combustion engine in which the warm-up system according to the invention is employed. An internal combustion engine 1 includes a plurality of cylinders 2, an intake passage 3 that introduces intake air to combustion chambers 2a formed in the respective cylinders 2, an exhaust passage 4 through which the exhaust gas flows from the combustion chamber 2a to a point where the exhaust gas is discharged, and an intake valve 5 and an exhaust valve 6 which are operated to connect or disconnect those passages 3, 4 with respect to the combustion chamber 2a. The intake passage 3 is provided with a compressor 7a of a turbo charger 7, an intercooler 8 for cooling a newly introduced air, and a throttle valve 9 for adjusting intake air quantity. The exhaust passage 4 is provided with an exhaust turbine 7b of the turbo charger 7, and a variable nozzle 7c that changes the

flow speed of the exhaust gas flowing into the exhaust turbine 7b. The opening degree of the variable nozzle 7c is adjusted by a DC motor 11. The exhaust passage 4 is connected to the intake passage 3 through an EGR passage 14 via an EGR cooler 12 and an EGR valve 13 for circulating a part of the exhaust gas into the intake passage 3.

[0022] The exhaust passage 4 is provided with a CO_2 absorbing and releasing agent 15 that is allowed to absorb CO_2 contained in the exhaust gas. Fig. 2 is an enlarged view of the CO_2 absorbing and releasing agent 15. As shown in Fig. 2, for example, the CO_2 absorbing and releasing agent 15 has a tubular shape with one plugged end, and an electric heater 16 disposed therein. The configuration of the CO_2 absorbing and releasing agent 15 is not limited to the tubular shape so long as it is capable of absorbing CO_2 contained in the exhaust gas and being heated to increase its temperature by the electric heater 16. An on/off state of the electric heater 16 may be selected by operating a switch 17. A known product may be employed as the electric heater 16, for example, mainly formed of a composite oxides of lithium such as lithium zirconate (Li_2ZrO_3), which functions in absorbing CO_2 in a first temperature range, for example, between 400°C and 580°C, and releasing the CO_2 in a second temperature range, for example, between 630°C and 700°C. Hereinafter, the first temperature range and the second temperature range will be occasionally referred as an absorption temperature range and a release temperature range, respectively.

[0023] Operations of the switch 17 of the electric heater 16 is controlled by an engine control unit (ECU) 18 formed as a known computer that controls operation states of the internal combustion engine 1. The ECU 18 performs a temperature control by executing control routines shown in the flowcharts of Figs. 3 to 5. The ECU 18 also controls operations of the throttle valve 9 or the DC motor 11 so as to adjust the intake air quantity in the internal combustion engine 1, or controls operations of the EGR valve 13 so as to adjust the quantity of the exhaust gas to be circulated into the intake passage 3. As the specific control methods as described above are well known, detailed explanations will be omitted.

[0024] The ECU 18 executes the control routine as shown in the flowchart of Fig. 3 such that the CO_2 absorbing and releasing agent 15 releases CO_2 for warming an intake manifold 3a in the intake passage 3 and the cylinders 2. The control routine shown in Fig. 3 is started immediately after activation of the ECU 18, and repeatedly

executed at a predetermined interval during the operation of the internal combustion engine 1.

[0025] In the control routine as shown in the flowchart of Fig. 3, it is determined whether a start-up of the internal combustion engine 1 has been commanded in step S11. The determination is made based on, for example, an operation state of an ignition switch. If it is determined that the operation state of the ignition switch is brought into an on state, it is determined that the start-up of the internal combustion engine 1 has been commanded. If it is determined that the start-up of the internal combustion engine 1 has not been commanded, the control routine at the present cycle ends. Meanwhile if it is determined that the start-up of the internal combustion engine 1 has been commanded, the process proceeds to step S12. In step S12, it is determined by the ECU 18 whether heating of the intake manifold 3a is prioritized. Such determination is made based on, for example, outside air temperature upon start-up of the internal combustion engine 1. If it is determined that the startability of the internal combustion engine 1 is deteriorated due to low outside air temperature, the determination is made to prioritize heating of the intake manifold 3a. If it is determined that the heating of the intake manifold 3a does not have to be prioritized, the control routine at the present cycle ends. Meanwhile, if it is determined that the heating of the intake manifold 3a has to be prioritized, the process proceeds to step S13. In step S13, the DC motor 11 is activated by the ECU 18 so as to fully close the variable nozzle 7c and to fully open both the EGR valve 13 and the throttle valve 9.

[0026] Then in step S14, the switch 17 is brought into an on state by the ECU 18 so as to activate the heater 16 for increasing the temperature of the CO_2 absorbing and releasing agent 15. In step S15, it is determined by the ECU 18 whether the heater stop condition has been established. The establishment of the heater stop condition may be determined when the time for heating the CO_2 absorbing and releasing agent 15 by the heater 16 passes a predetermined time. The predetermined time is set to the value derived from dividing the upper limit of the amount of CO_2 that can be absorbed by the CO_2 absorbing and releasing agent 15 by the speed of releasing CO_2 from the CO_2 absorbing and releasing agent 15. The predetermined time may be set to the value as the upper limit of time for which the temperature of the CO_2 absorbing and releasing agent 15 is maintained in the second temperature range. The aforementioned setting of the predetermined time makes it possible to

prevent unnecessary heating of the CO_2 absorbing and releasing agent 15. The establishment of the heater stop condition may be determined when it is determined that start-up of the internal combustion engine is performed. If CO_2 as inert gas is continuously supplied to the intake passage 3 even after start-up of the internal combustion engine 1, the combustion therein may be deteriorated. Accordingly the heater 16 is stopped after start-up of the internal combustion engine 1 so as to restrain the combustion deterioration. If it is determined that the heater stop condition has not been established, the control routine at the present cycle ends. If it is determined that the heater stop condition has been established, the process proceeds to step S16 where the switch 17 is brought into an off state to stop the heater 16. Then the control routine ends.

[0027] Execution of the control routine as shown in Fig. 3 may introduce the high temperature CO_2 released from the CO_2 absorbing and releasing agent 15 into the intake manifold 3a for promoting warm-up of the intake manifold 3a and the cylinders 2. In the control routine of Fig. 3, the order for executing steps S13 and S14 may be inversed.

[0028] The ECU 18 executes the control routine as shown in the flowchart of Fig. 4 for releasing CO_2 from the CO_2 absorbing and releasing agent 15 and warm an exhaust gas purification catalyst 10. The control routine shown in Fig. 4 is started immediately after activation of the ECU 18, and repeatedly executed at a predetermined interval during the operation of the internal combustion engine 1. Steps in the flowchart of Fig. 4 that are the same as those in the flowchart of Fig. 3 are designated as the same reference numerals, and the explanation thereof, thus, will be omitted.

[0029] Referring to the control routine in Fig. 4, it is determined whether a start-up of the internal combustion engine 1 has been commanded in step S11. If it is determined that the start-up of the internal combustion engine 1 has not been commanded, the control routine at the present cycle ends. Meanwhile if it is determined that the start-up of the internal combustion engine 1 has been commanded, the process proceeds to step S21. In step S21, it is determined by the ECU 18 whether the temperature of the catalyst 10 is equal to or lower than the catalytic activation temperature. The temperature of the exhaust gas purification catalyst 10 may be detected by a temperature sensor provided in the catalyst 10 or obtained by estimating the exhaust gas temperature based on the quantity of the fuel supplied to

the internal combustion engine 1. If it is determined that the temperature of the catalyst 10 is higher than the catalytic activation temperature, the control routine at the present cycle ends. Meanwhile if it is determined that the temperature of the catalyst 10 is equal to or lower than the catalytic activation temperature, the process proceeds to step S22. In step S22, the variable nozzle 7c is fully opened and the throttle valve 9 is fully closed by the ECU 18. Thereafter the same steps as those shown in Fig. 3 are executed, and the control routine at the present cycle ends.

[0030] Execution of the control routine shown in Fig. 4 introduces CO_2 released from the CO_2 absorbing and releasing agent 15 into the exhaust gas purification catalyst 10 for promoting the warm-up thereof, that is, heating of the exhaust gas purification catalyst 10 to reach the temperature equal to or higher than the catalytic activation temperature. In the control routine of Fig. 4, the order for executing steps S22 and S14 may be inversed.

[0031] The control routine shown in Fig. 3 and the control routine shown in Fig. 4 may be independently executed or combined together. In the case where those control routines are combined, the respective control routines may be executed based on the prioritized order, or executed in parallel. The exhaust gas purification catalyst 10 may be heated to reach the temperature equal to or higher than the catalytic activation temperature before the internal combustion engine 1 is brought into an operation state. When improvement of the startability of the internal combustion engine 1 is prioritized, the control routine shown in Fig. 3 may be executed prior to the control routine shown in Fig. 4.

[0032] The ECU 18 executes a control routine shown in the flowchart of Fig. 5 such that the CO_2 absorbing and releasing agent 15 absorbs CO_2 for the purpose of releasing sufficient amount of CO_2. The control routine shown in Fig. 5 may be executed upon a command for stopping the internal combustion engine 1, for example, operation of the ignition switch into the off state, and repeatedly executed at a predetermined interval.

[0033] In the control routine shown in Fig. 5, in step S31, it is determined by the ECU 18 whether a rate of the total amount of CO_2 absorbed in the CO_2 absorbing and releasing agent with respect to the upper limit value of the amount of CO_2 absorbed in the CO_2 absorbing and releasing agent 15 is equal to or lower than a standard rate F%. The standard rate F% is set to the value indicating the rate of the amount of CO_2 sufficient to warm the intake manifold 3a or the exhaust gas

purification catalyst 10 with respect to the upper limit value of the amount of the CO_2 that can be absorbed in the CO_2 absorbing and releasing agent 15. The total amount of absorbed CO_2 is calculated by the routine shown in the flowchart of Fig. 6 to be described later. If it is determined that the amount of CO_2 absorbed in the CO_2 absorbing and releasing agent 15 is equal to or lower than the standard rate F%, the process proceeds to step S32. In step S32, it is determined by the ECU 18 whether the temperature of the CO_2 absorbing and releasing agent 15 is equal to or lower than a lower limit of the absorption temperature range. The temperature of the CO_2 absorbing and releasing agent 15 may be detected by a temperature sensor provided for the CO_2 absorbing and releasing agent 15, or obtained in reference to the exhaust gas temperature estimated based on the quantity of fuel supplied to the internal combustion engine 1. If it is determined that the temperature of the CO_2 absorbing and releasing agent 15 is equal to or lower than the lower limit of the absorption temperature range, the process proceeds to step S33 where the switch 17 is operated to an on state for activating the heater 16 by the ECU 18 so as to heat the CO_2 absorbing and releasing agent 15 to reach the absorption temperature range. The control routine then ends. If it is determined that the amount of CO_2 absorbed in the CO_2 absorbing and releasing agent 15 is not equal to or lower than the standard rate F% in step S31, and the temperature of the CO_2 absorbing and releasing agent 15 is not equal to or lower than the lower limit of the absorption temperature range, the process proceeds to step S34. In S34, the heater 16 is stopped by the ECU 18, and the control routine ends.

[0034] Execution of the control routine shown in Fig. 5 allows the CO_2 absorbing and releasing agent 15 to absorb sufficient amount of CO_2 to be released upon subsequent start-up of the internal combustion engine 1. The ECU 18 is structured to execute the control for continuously operating the internal combustion engine 1 until the CO_2 absorbing and releasing agent 15 absorbs CO_2 by amount sufficient for the subsequent start-up of the internal combustion engine 1, that is, the control for extending the time for stopping the internal combustion engine 1. This may allow the CO_2 absorbing and releasing agent 15 to absorb sufficient amount of CO_2. The CO_2 absorption efficiency of the CO_2 absorbing and releasing agent 15 is improved especially when the CO_2 concentration of the exhaust gas is high and the exhaust gas quantity is small. Accordingly, the heater 16 may be activated to allow the CO_2 absorbing and releasing agent 15 to absorb CO_2 during the operation of the

internal combustion engine 1 at a high load and a low speed such that the exhaust gas is brought into the aforementioned state. The CO_2 absorbing and releasing agent 15 is then allowed to absorb CO_2 by larger amount with the same consumption energy compared with the other operation state of the internal combustion engine 1. The amount of CO_2 to be absorbed by the CO_2 absorbing and releasing agent 15 is reduced after the command for stopping the internal combustion engine 1 is issued so as to reduce the energy consumed by the heater 16.

[0035] A flowchart shown in Fig. 6 represents a routine for calculating a total amount of CO_2 absorbed in the CO_2 absorbing and releasing agent 15 executed by the ECU 18. The routine shown in Fig. 6 is repeatedly executed during the operation of the internal combustion engine 1 at a predetermined interval.

[0036] In the routine shown in Fig. 6, it is determined by the ECU 18 whether the temperature of the CO_2 absorbing and releasing agent 15 is in the absorption temperature range in step S41. If it is determined that the temperature of the CO_2 absorbing and releasing agent 15 is in the absorption temperature range, the process proceeds to step S42 where an amount of CO_2 absorbed in the CO_2 absorbing and releasing agent 15, ΔCO_2add, is calculated by the ECU 18. The value of the ΔCO_2add is obtained based on parameters such as the CO_2 concentration and the flow rate of the exhaust gas as it varies depending thereon. In step S43, the ECU 18 adds the value of ΔCO_2add to the total amount of absorbed CO_2, that is, CO_2strg_{i-1} that has been calculated in the previous cycle of the routine shown in Fig. 6 to obtain a total amount of absorbed CO_2, that is, CO_2strg_i. The control routine at the present cycle ends.

[0037] If it is determined that the temperature of the CO_2 absorbing and releasing agent 15 is not in the absorption temperature range, the process proceeds to step S44 where it is determined by the ECU 18 whether the temperature of the CO_2 absorbing and releasing agent 15 is in the release temperature range. If it is determined that the temperature of the CO_2 absorbing and releasing agent 15 is in the release temperature range, the process proceeds to step S45 where the ECU 18 calculates an amount of CO_2 released from the CO_2 absorbing and releasing agent 15, that is, ΔCO_2sub. The value of ΔCO_2sub is calculated based on parameters such as the CO_2 concentration and the flow rate of the exhaust gas as it varies depending thereon. In step S46, the ECU 18 subtracts the value of ΔCO_2sub from the value CO_2strg_{i-1} that has been calculated in the previous cycle of the routine shown in Fig. 6 to obtain the

total amount of absorbed CO_2, that is, CO_2strg_i. The control routine at the present cycle then ends.

[0038] If it is determined that the temperature of the CO_2 absorbing and releasing agent 15 is not in the release temperature range, the process proceeds to step S47 where the ECU 18 substitutes the value of CO_2strg_{i-1} that has been calculated in the previous cycle of the routine shown in Fig. 6 for the value CO_2strg_i. The control routine at the present cycle ends.

[0039] The routine shown in Fig. 6 is executed to calculate the total amount of the absorbed CO_2 by adding or subtracting the amount of CO_2 absorbed in or released from the CO_2 absorbing and releasing agent 15. The calculated value of the total amount of absorbed CO_2 is stored in a RAM of the ECU 18 so as to be referenced upon execution of the subsequent cycle of the routine shown in Fig. 6 or the control routine shown in Fig. 5.

[0040] Fig. 7 shows another type of the internal combustion engine 1 in which a warm-up system according to the invention is employed. The elements shown in Fig. 7 that are the same as those shown in Fig. 1 are designated as the same reference numerals. The internal combustion engine 1 shown in Fig. 7 is substantially the same as that shown in Fig. 1 except that the CO_2 absorbing and releasing agent 15 is provided downstream of the turbine 7b and upstream of the exhaust gas purification catalyst 10. In the case where the CO_2 absorbing and releasing agent 15 is placed as aforementioned, the warm-up of the exhaust gas purification catalyst 10 may be promoted by the ECU 18 that executes the control routine shown in the flowchart of Fig. 8. The control routine shown in Fig. 8 is started immediately after activation of the ECU 18 and is repeatedly executed at a predetermined interval. Steps in Fig. 8 that are the same as those in Fig. 4 are designated as the same reference numerals and explanations thereof, thus, will be omitted.

[0041] In the control routine shown in Fig. 8, the process is the same as that shown in Fig. 4 until step S21. If it is determined that the temperature of the exhaust gas purification catalyst 10 is equal to or lower than the catalytic activation temperature, the process proceeds to step S51 where the variable nozzle 7c is fully closed by the ECU 18. The process is executed in the same manner as in the control routine shown in Fig. 4, and the control routine at the present cycle ends.

[0042] In the case where the CO_2 absorbing and releasing agent 15 is placed at a position as shown in Fig. 7, the variable nozzle 7c is fully closed to block the flow

of the CO_2 to the upstream of the turbine 7. The amount of CO_2 flowing into the exhaust gas purification catalyst 10 is then increased to promote the warm-up of the exhaust gas purification catalyst 10. In the control routine shown in Fig. 8, the order for executing steps S51 and S14 may be inversed.

[0043] The invention may be structured into arbitrary forms without being limited to the aforementioned embodiments. The position at which the CO_2 absorbing and releasing agent is placed is not limited to the exhaust passage so long as it is able to absorb CO_2 contained in the exhaust gas. The CO_2 absorbing and releasing agent may be placed in the EGR passage. The number of the CO_2 absorbing and releasing agents to be used and positions thereof may be arbitrarily determined. A plurality of CO_2 absorbing and releasing agents may be provided around a plurality of components that need to be warmed such that high temperature CO_2 can be supplied directly to those components. The heating unit is not limited to the electric heater. A combustion type heater may be employed for heating the CO_2 absorbing and releasing agent.

[0044] The components in the internal combustion engine, which need to be warmed are not limited to the exhaust gas purification catalyst, intake manifold, and cylinders. A lubricating oil tank may be provided such that heat exchange can be performed between the released CO_2 and the lubricating oil for smoothly increasing the temperature of the lubricating oil upon start-up of the internal combustion engine in order to prevent deterioration in the startability thereof caused by high viscosity of the lubricating oil. The warm-up of the internal combustion engine may be promoted by supplying heat of CO_2 released from the CO_2 absorbing and releasing agent into various components that need to be warmed.